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ABSTRACT

Empirical work in industrial research organizations has provided data to describe researcher behavior during innovation. Based on these data, the role of information during idea creation and submission is described. A model of a management information system, consistent with and supportive of researcher behavior, is structured to include technical planning, project selection, and manpower planning. The critical problems of information search and dissemination are examined. (Author/RA)

INFORMATION AND INNOVATION IN RESEARCH ORGANIZATIONS*

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Empirical work in industrial research organizations has provided data sufficient to describe researcher behavior during innovation. The role of information during idea creation and idea submission is described based on these data. A model of a management information system is structured which is consistent with and supportative of researcher behavior and which includes technical planning, project selection, and manpower planning. The critical problems of information search and dissemination are examined.

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A properly functioning research activity requires a periodic flow of ideas for researchable problems as a necessary input. Once ideas have come to the attention of the research activity much still remains to be done before any results are realized. Each idea must be reviewed; good alternative technical approaches for researching the idea formulated; one, or at most few, alternatives selected for project effort; project effort properly implemented and monitored; and project results evaluated and communicated to potential users. The list is far from exhaustive. Only after all these steps have been accomplished can one say the research activity has completed its function. While recognizing this, the primary focus of the paper will be on the creation, submission, and continued development of ideas. The underlying tenet is that an input of high quality ideas is a necessary, but not sufficient, condition for a research activity to function properly. The objective of this paper is to discuss the impact of information flow on the quality and quantity of this necessary input (ideas) and to develop a management information system which is consistent with and supportative of the innovative behavior (idea generation and submission).

The Innovative Process Viewed As A Behavioral Process

Drawing on Rubenstein (11), an idea is defined as "a potential proposal for undertaking new technical work which will require the commitment of significant organization resources such as time, money, energy." The phrase "potential proposal" denotes that the idea has not been communicated to a person who has organizational authority to allocate resources (a "reviewer") or who has responsibility to communicate the idea to a reviewer. A "proposal" is an idea which has been submitted to an organizational reviewer. A "project" is a proposal which has had resources allocated to it.

Figure 1 is a flow model which identifies some of the activities and decision points which arise from consideration of how ideas are created and submitted, proposals are reviewed, and projects are investigated, implemented, and evaluated. Following the primary flow (the solid line flow), one observes that there are many opportunities for the research activity to depart from "optimal" behavior. The first two such opportunities occur before management has an opportunity to exert direct influence or control, namely during idea creation and submission. It is these two subprocesses which will be investigated in detail. However, before beginning the detailed discussion, it is important to delineate the over-all process as summarized in Figure 1.

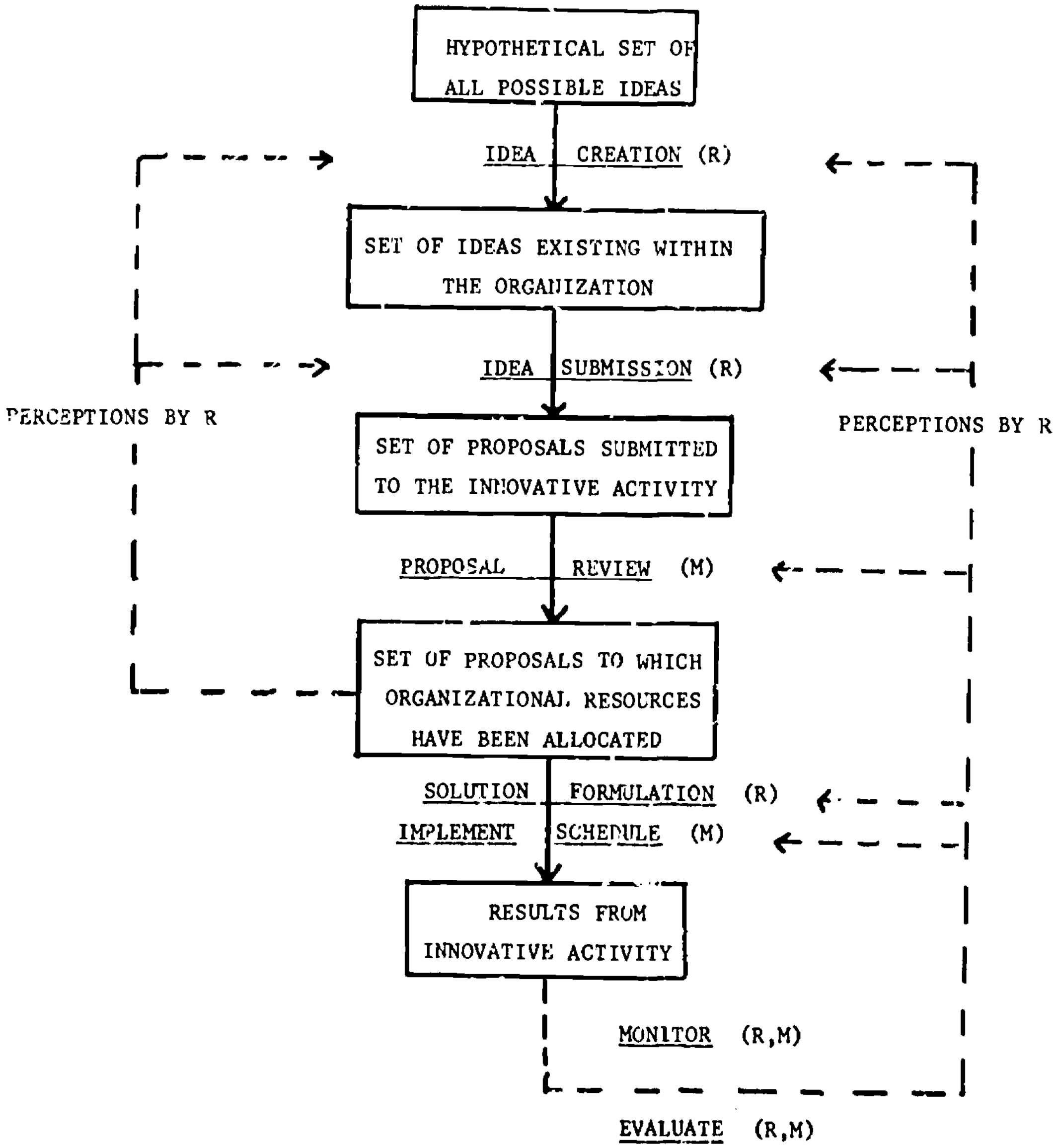
The idea flow is initiated when some innovator, or group of innovators, create one or more ideas. In the flow model, this is depicted as a filter or screen which operates on a hypothetical set of all possible ideas. Because of creative effort, some subset of the possible ideas is actually recognized by the innovator(s). This subset, probably much smaller than the potential set, can be viewed as the set of ideas which exist within the organization due to internal creative effort. Note that the quality and quantity of ideas which are recognized, i.e., which exist within the organization, is directly dependent upon the creative behavior of the innovators and is not under the direct control of the managers of the research activity. Management can influence, and hopefully improve, this creative effort both by their behavior and by properly managing the flow of information.

It is not sufficient for ideas to be created. If the research activity is to have the opportunity to utilize these ideas, then the innovator must communicate his ideas to a reviewer. It is important to note that the innovator may or may not be a member of the research activity. If he is not a member, then the barriers of communication may be greater than if he is a member. Regardless, the flow model identifies this process as idea submission and the result is a set of proposals which has been submitted to research management for their consideration. Thus, a second screening has been introduced which further influences the quality and quantity of ideas which are available to the research activity.

FIGURE 1

BEHAVIORAL MODEL OF THE

RESEARCH ACTIVITY



⟶ denotes "primary flow". - - → denotes "feedback".

(R) denotes "typically under control of researcher".

(M) denotes "typically under control of manager".

There has been considerable discussion and speculation regarding whether ideas are created, but not submitted and, if so, whether the ideas which are not submitted are "good" or "poor" ideas. The ideal case is that all "good" ideas should be submitted, but "poor" ideas should be screened prior to submission. Recent research resulted in data which indicate that, in the organization studied, ideas where being created which were not being submitted. Further, when compared against other ideas ("control" ideas) existing within the organization, subjective ratings of quality elicited from a panel of qualified judges reveal that the ideas which were not submitted contained a significantly higher proportion of "good" ideas. These data are summarized in Tables 1A and 1B. A mechanism was developed whereby the ideas not submitted during the normal operation of the organization became submitted and reviewed by management. At the time of review management did not know the results of the subjective evaluations. The managerial review decisions also indicated a relatively high percentage of quality ideas in the set of "not submitted" ideas (Table 1C). Perhaps the most startling finding was that 38% of the ideas achieving project status came from the "not submitted" set which contained only 15% of the total ideas. Thus, the process of idea submission should be studied and better understood.

The remainder of Figure 1 deals with activities which, while critical to the performance of the research activity, are not central to the focus of this paper. The feedback (broken line flow) from these activities to idea creation and submission is, however, crucial to the paper. It will be shown later that these feedbacks determine the influence of managerial behavior on idea creation and submission. Note that the feedback consists of the innovators' perceptions of managerial behavior and not of the elicited behavior per se.

The Role of Information In Creativity

Let us define an idea to be "generated" when the originator or innovator is willing to communicate it t others, i.e., the idea has been created developed to the point that the idea originator is willing and able to verbalize it. Recent empirical evidence (5) suggests that two pieces of

COMPARATIVE RATINGS OF "NOT SUBMITTED"

AND "CONTROL" IDEAS

TABLE 1A

Rating / Status	Excellent, Good	Fair, Poor	Total
Not Submitted	28	19	47
Control	88	168	256
Total	116	187	303

TABLE 1B

Rating / Status	"Best"	"Not Best"	Total
Not Submitted	13	34	47
Control	36	220	256
Total	49	254	303

TABLE 1C

Disposition Decision / Status	Project Status	Shelved	Communicated, No Response	Rejected	Totals
Not Submitted	11	6	4	26	47
Control	18	43	18	177	256
Total	29	49	22	203	303

WHERE: 1) "Best" indicates that 2 or more of 7 judges selected the idea as "one of the 10 or 15 best ideas out of the 303 total ideas."

2) "Project Status" — idea became new project or task in an on-going project.
"Shelved" — management decided to postpone the disposition decision.
"Communicated, No Response" -- idea judged to be more relevant to another company division and was communicated, but there has been no response.
"Rejected" -- idea was rejected as a new project or task.

For all three sets of data, the hypothesis that the distribution of ideas into categories is independent of the status can be rejected at the .05 level of significance by a chi-square test of independence.

information are necessary for generating an idea:

1. Recognition of an organizational need, problem, or opportunity which is perceived to be relevant to organizational objectives, and,

2. Recognition of a means or technique by which to satisfy the need, solve the problem, or capitalize on the opportunity.

Let us refer to the event leading to the recognition of a relevant need, problem, or opportunity as a "need event" and to the event leading to the recognition of the means or technique as a "means event". The authors report that "need events" were identified for 94% of 268 ideas and "means events" for 92% of 268 ideas. By definition "means" oriented information is technical in nature where "need" information is organizational.

Baker, Siegman, and Rubenstein were also able to identify the specific events which functioned as "need" and "means" events. Further, it was possible to identify which event occurred first and thus stimulated the idea. This event will be referred to as a "stimulating event". The specific events identified were:

1. "Thinking by self" which included such items as "I knew of the need for such a product", "Through experience, I knew that such an approach was possible", "I saw the operation and knew that it could be done better", "It is basically a modification of someone else's idea", "I was working on something else and this happened by accident", etc.

2. "Interaction" which included such items as "Manager X discussed the need for such a product at the first group meeting", "Y indicated that his group was trying to solve this problem and had not been successful", "Z was telling me about one of his pet peeves and the idea came to me".

3. The study participants were encouraged to visit other company locations, to visit with customers, and to attend professional meetings, industrial fairs, and design shows. When the respondent indicated that such a visit or trip served as an information source to an idea, the response was included under "company events".

4. The study participants were provided with such information as potential markets, sketches of earlier ideas, a set of old patent drawings, etc. Such events were called "company tools".

5. "Library" included such responses as "I read in a trade journal about how such a thing might work". "I read how company Z was doing this for another reason", "X was proposing this procedure in a company technical report", etc.

The respective roles and importance of these information sources is summarized in Table 2. It is interesting to note the dominant roles played by "interaction" and "thinking by self" as "need", "means", and "stimulating" events. The numbers in the upper left of each cell indicate the total number of ideas for which the associated source provided information that was used as the associated event. Numbers in the lower right of each cell give the number of ideas subjectively rated to be in the "excellent" and "good" categories for each pair of information source and event. Since for some ideas more than one source was identified, the column sum may exceed 268 which is the total number of ideas identified by the study.

In summarizing their observations, Baker, Siegman, and Rubenstein note two underlying behavior patterns. In the first pattern, a "need event" occurred which suggested the possibility for an idea relevant to organizational objectives. Subsequently, some "means" were discovered, thus generating an idea. "Means" identification occurred either nearly simultaneously with "need" recognition or was developed over time. This general pattern was called a "need-means" pattern and was observed as being associated with 80% of the ideas identified. In this case, the "need event" stimulated the idea. The remaining 20% of the ideas followed a "means-need" pattern. Although recognition of a "need" stimulated more ideas than recognition of a "means", the distribution of ideas into subjective categories of quality was independent of the nature of the stimulating event. The authors stress that the data were collected within one division of a single organization.

TABLE 2

SUMMARY DATA ON INFORMATION SOURCES

	STIMULATING EVENTS		NEED EVENTS		MEANS EVENTS	
THINKING - BY - SELF	73	23	118	41	173	59
INTERACTION	114	49	107	47	57	19
COMPANY EVENTS	38	17	27	12	18	8
COMPANY TOOLS	29	4	19	2	11	8
LIBRARY	17	7	0	0	10	7
	271	100	271	102	269	101

where:

Total number	
	Number rated E thru G -

The Role of Information in Idea Submission

The non-management members of a research activity have the responsibility to perform two activities: 1) to generate new ideas and 2) to carry out research activity on current projects. While these two behaviors have some aspects in common, they also have many aspects which are quite different.

In most organizations, highly visible rewards such as merit wage increases, advancement opportunities, good job assignments, and job security are provided by the organization for effort expended on current project assignments. Especially since the advent of such planning and scheduling methodologies as PERT, these same organizations have built-in, operating mechanisms for reviewing achievement relative to specific deadlines and budget goals. Frequently there is an implicit or explicit failure to reward, or perhaps punish, if these goals are not realized. Thus, organizational pressures exist to focus researcher attention on the current project activity.

The organizational review mechanism with respect to idea flow is not as well-defined and organizational rewards for achievement relative to the creation and submission, although potentially greater, are not as certain. Hence there is a tendency to attach different rewards to this activity; for example, recognition from peers, opportunity to publish, or opportunity to determine future assignments. In short, idea strategy for obtaining organizational rewards because the mechanisms for scheduling review and measuring achievement are less well-defined.

Avery (1) and Marcson (9), as well as many other authors, have demonstrated that management is more likely to evaluate an idea and to reward the originator if the idea is "relevant". An idea is perceived by management as relevant if it 1) satisfies an existing (urgent) need or solves an existing (urgent) problem, 2) can be developed into a new project which is compatible with the organization's over-all goals and objectives, and 3) can be investigated with existing laboratory resources and facilities (1,4). Considerations one and two are "need" related and item three is "means" related; hence, an idea is relevant if both the "need" and "means" are relevant. Not only do managers behave as described, but the non-management staff accurately perceives this behavior (3,4,8) and, accordingly, generate and submit ideas expected to judged by management as relevant. Thus, "need" and "means" information plays a critical role in idea creation, submission, and review.

In order to obtain empirical insight into idea submission, detailed case histories were developed for almost all of the 47 "not submitted" ideas. The case histories and related researcher-management interactions are detailed in (3). For each idea it was possible to identify the factor which was cited as the primary reason the idea was not submitted or, for ten of the ideas, not resubmitted. These factors, frequency of citation for each factor, and subjective quality of the associated idea are summarized in Table 3. The importance of time deadlines on current work and of expectations concerning the relevance as perceived by management is clearly illustrated.

Based on the case histories and related interactions, it is argued that because of organizational review and reward mechanisms which focus attention on current project activity and because of the uncertainty inherent in the review and reward mechanisms associated with idea flow, research personnel tend not to function to their full creative potential with respect to idea generation. Ideas are created only if "need" and "means" can be identified and ideas are submitted only if the orginator believes that the underlying "need" and "means" will be perceived by management as relevant and only if actual rewards expected are equal to the cost of creation, for the individual. Unfortunately, relevancy is time and reviewer dependent; e.g., and idea judged "not relevant" at one point in time may be judged "relevant" by the same reviewer at another point in time or one reviewer may judge an idea "relevant" at the same time another reviewer would judge the idea "not relevant". Further, since expectations regarding reviewer

TABLE 3

SUMMARY OF FACTORS RESULTING
IN IDEAS NOT SUBMITTED

Factors	N	%	Idea Ratings		
			Fair, Poor	Good, Excellent	Best
Time Pressures	28	60%	14	14	4
Anticipated Negative Evaluation From Management	4	9%	0	4	2
Negative Evaluation From Peers	3	6%	1	2	1
Negative Evaluation By Group Leader	2	4%	1	1	1
Previously Rejected By Management	2	4%	2	0	0
Submitted, No Response	8	17%	1	7	5
Total	47	100%	19	28	13

evaluation are based primarily on reviewer actions on previous ideas, there can be a significant lag between the time reviewers change their behaviors and the time idea originators perceive the change.

Submitted ideas often are not sufficiently developed technically and not sufficiently supported by evidence of relevance that management can "objectively" evaluate them. The lack of completeness is explained by the idea originator investing minimum time on idea development because of pressures for current work accomplishment, of uncertainty regarding rewards from idea generation, and of lack of knowledge regarding relevant "need" and "means". Since management is unable to evaluate the "incomplete" ideas, they behave in ways perceived by the idea originators as non-rewarding and costly; e.g., typical responses are "develop on your spare time," "state of the art not sufficiently advanced," "too far out," or no response at all. Thus, expectations regarding organizational rewards for idea flow effort are modified downward and the cycle is ready to repeat. As new employees enter the organization they learn these low expectations from the veterans who have traversed full cycle. In such an environment it is little wonder that potentially creative employees fail to realize their potential and appear to "go dry" over time.

While the preceding is a somewhat pessimistic characterization of the environment, it does illustrate the sensitivity of the innovative environment. Information of technical and organizational nature is required at points in time when current work presures are sufficiently relaxed to permit the generation and submission of relevant ideas. There is a requirement for an information system which:

1. results in more consistency in evaluations performed by different reviewers.
2. can be easily updated as the environment and the information base change.
3. has researcher involvement in both input and output.

4. decreases the lag in feedback to idea originators.

5. generates timely "need" and "means" information.

Technical Planning: An Information Source

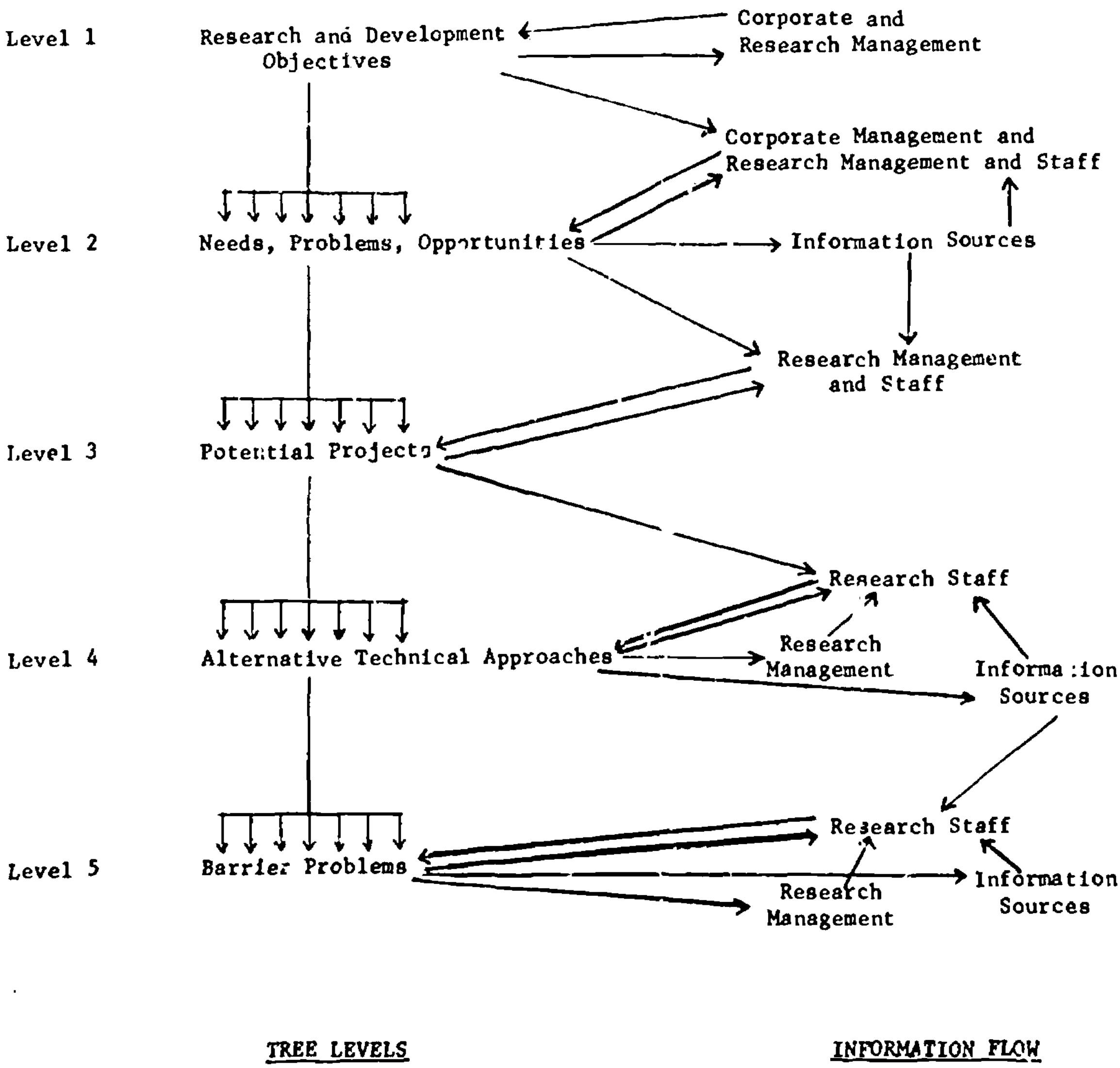
Several authors (2, 12) have suggested relevance trees for accomplishing technical planning. Although the specific defintions of the trees vary, the underlying structures are identical. To illustrate the concept, consider the following example with the levels of the tree defined to be consistent with the descriptive results.

Assume that a set of research and development objectives have been established which are consistent with the superordinate objectives of the organization. An example objective is to "eliminate pollution from production processes and products." Working from the objectives, develop a list of specific needs, problems, and opportunities, e.g., "develop a pollution free automobile." For each need, problem and opportunity identify several potential projects such as "construct a marketable electric powered automobile." One or more alternative technical approaches should be established for each potential project; e.g., "power the automobile by a storage cell." Finally, for each technical approach, establish the barrier problems which are the advances necessary for the technical approach to be successfully completed. For example, "the storage cell must be capable of driving the vehicle at speeds up to 80 miles an hour for extended periods of time."

The relevance tree for the levels defined in the preceding example is outlined in Figure 2. The associated information flow clearly illustrates the opportunity the research staff has for idea flow effort by inputting ideas for potential projects, ideas for technical approaches, and identification of barrier problems. Further, levels 1 and 3 provide the information necessary for both management and staff to determine the relevancy of the ideas. Thus, initial specification of the relevance tree should result in more consistent

FIGURE 2

ILLUSTRATIVE RELEVANCE TREE LEVELS
WITH ASSOCIATED INFORMATION FLOW



evaluation by reviewers and does provide for research involvement in both input and output.

Important "need" and "means" information is also obtainable from the initial specification. Objectives for which few needs, problems, or opportunities are defined; needs problems, and opportunities for which few potential projects exist; projects for which satisfactory technical approaches are not identified; and technical barrier problems which remain to be overcome all identify weaknesses in the plan and signal possibilities for idea effort. As indicated by the associated information flow, this information is not only important for the research management (for review of ideas and update of the plan) and the research staff (for generation of ideas and focus of effort), but also for the various information sources such as the library or the computer services section (to help structure what information to search for and disseminate). Hence, continual updating of the relevance tree can increase researcher involvement, decrease the lag in feedback, and assist the information sources in generating timely "need" and "means" information.

Dean and Hauser (6) and Freeland (7) have shown that if estimates of costs and of associated probabilities of success are avialable at levels 4 and 5 and if costs and project values are available at level 3, then dynamic programming can be used to optimize the funding pattern subject to budget constraints. The optimization can be performed for several different objective functions; e.g., Dean and Hauser cite nine different optimization criteria. Thus, it is possible to generate several funding patterns each optimal with respect to at least one decision criterion and to search for a project selection and funding pattern which is acceptable relative to all the criteria.

The ability to mathematically optimize over levels 3, 4, and 5 is also importsnt for information flow. In addition to optimizing over given estimates of cost and probabilities of success for technical approaches and for barrier problems, the value impact of improvements in probabilities of success and/or decreases in cost can be measured. The output from such a sensitivity analysis will identify those technical approaches and barrier problems for which a reduction in cost and/or an increase in probability of success would contribute most to the research plan. This information should be communicated to the research staff to stimulate ideas and to the information sources to assist in identifying user information needs. In addition, as ideas are submitted for new projects, technical approaches, or means for solving barrier problems, these ideas can be augmented to the tree and the modified tree can be analyzed. Such an approach should provide for more consistent idea review and faster feedback to the idea originators. Clearly, the tree should be updated at levels 1 and 2 as environmental changes dictate or as corporate management redefines the superordinate objectives.

In summary, an information flow can be built around the relevance tree which satisfies the five requirements established as a result of the behavioral studies. Further, dynamic programming can be used to optimize any existing tree and to provide critical "need" and "means" information for idea flow. Information sources become an integral part of the information flow and are provided with the input necessary to determine what specific information should be searched for and disseminated.

Manpower Planning: Timing of Information

One output from the dynamic programming optimization is the optimal dollar support for each project broken down into dollar support for each technical approach and for each barrier problem. If each barrier problem, often referred to as a research task, is independent and can be performed by only one type of research skill (JO) or, alternatively, if the types of skill necessary to overcome a barrier problem can be identified, then the dollar support for each barrier problem can be converted into skill man-hour requirements. Thus, the research organization could summarize its total manpower requirements according to the total number of man-hours of each research skill required to accomplish the research plan.

Under the additional assumptions that within a skill all persons are equally effective in working on a relevant task and that the amount of available man-hours in a skill is not restricted, a linear programming manpower allocation maodel can be constructed. Let p_i be the due date for project i and B_{ilt} be the total man-hours of skill l required by project i in or before t, then a model which minimizes the variation in man-hours scheduled for a skill between successive time periods is:

for each skill l = 1, 2, ..., L

$$\text{minimize} \quad \sum_{t=1}^{T-1} \left| \sum_{i=1}^{m} x_{ilt} - \sum_{i=1}^{m} x_{il(t+1)} \right|$$

subject to:

$$\sum_{t=1}^{p_i} x_{ilt} = B_{ilp_i} \qquad \text{for each } i = 1, 2, \ldots, m$$

$$\sum_{t=p_i+1}^{T} x_{ilt} = 0 \qquad \text{for each } i = 1, 2, \ldots, m$$

$$x_{ilt} \geq 0 \qquad \text{for all } ilt$$

where

$t = 1, 2, \ldots, T$ time periods

$l = 1, 2, \ldots, L$ skills

x_{ilt} = number of man-hours of skill l allocated to project i in time period t.

There is no restriction preventing all available manpower from working on one [illegible]ect at a time or from assigning a small number of man-hours for each time [illegible]d to every project. Realistically, if this were the case, then the phasing in and out, the coordination, and the management of the projects could become cumbersome and difficult. Imposing upper bound or lower bound constraints, i.e., $v_{ilt} \leq x_{ilt} \leq u_{ilt}$, would partially alleviate this shortcoming. Regardless, the model can be written in a linear programming format (7) and the output is the nucleus for a manpower allocation.

Additional constraints can be added to the model to ensure that the amount of available skill is not exceeded. Let A_{tl} be the number of man-hours of skill l available in the t^{th} time period. Then constraints of the form

$$\sum_{i=1}^{m} x_{ilt} \leq A_{tl} \qquad \text{for each } t = 1, 2, \ldots, T$$

can be imposed. Because of the A_{tl} and B_{ilp_i} constraints could be inconsistent, it is possible that no feasible solution will exist. Fortunately it is easy to check for the existence of a feasible solution. If a feasible solution exists, then the model can be solved by linear programming methods.

For each time period $t_o = 1, 2, \ldots, T$, define

$$b_{ilt_o} = \sum_{t=1}^{t_o} A_{tl} - \sum_{i=1} \sum_{t=1}^{t_o} B_{ilt}.$$

If $b_{ilt_o} \leq 0$ for each time period, then a feasible solution exists for skill l.

For all t_o where $b_{lt_o} < 0$, the constrained problem is not feasible. If this test is performed for all skills and time periods, then it will be known which skills and which time periods are responsible for the infeasible solution. Management must then decide whether to acquire additional skills, e.g., by hiring or contracting, or to modify the plan by delaying projects or decreasing skill support.

Using the information generated by the model and by analysis of b_{lt_o} (the surplus or deficit of skill l in period t_o), research management should be able to formulate a manpower allocation plan. For each skill, l, the first [illegible]e period, t, for which $x_{ilt} > 0$ is the starting time period for skill l effort on project i, and the first t for which $x_{ilt} > 0$ for any skill l is the starting time period for support to project i. Finally, it is noted that $b_{lt_o} > 0$ is a rough measure of the time available by skill l personnel for idea flow effort. During such a period, information flow from research management and from information sources could be structured to stimulate idea effort directed toward weak areas in the plan or toward critical technical approaches or barrier problems.

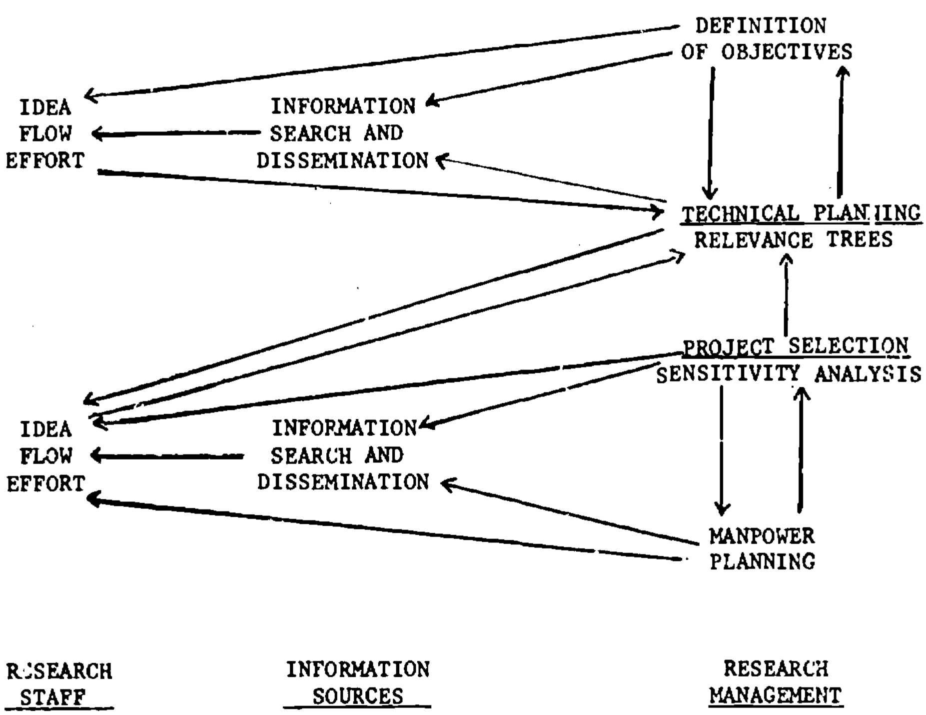
Summary and Discussion

A model of an information system is developed which is consistent with and supportative of the behavior of innovators during the innovative process. Technical plans in the form of relevance trees are shown to provide for the identification of relevant information and the timing of information flow. Project selection and manpower planning is included in the process and the output from these subsystems further specifies the identification and timing, as well as the routing, for the information sources. Figure 3 summarizes the information system and illustrates that three relevant groups of participants -- researchers, information sources, and managers -- interact within the system.

Management science, both as a discipline and as applied to research management in specific, has developed a wealth of descriptive knowledge and normative methodlology. The descriptive and normative studies have tended to be conducted independently. Management science, however, has now matured to the point where applications can integrate description and methodology to structure behaviorally feasible systems. The system developed in this paper is one such example. Additional work is required on such critical problems as parameter estimation, value measurement, and information source design. However, current knowledge and methodology is sufficient to structure a normative system which is consistent with and complementary to researcher behavior.

FIGURE 3

SUMMARY OF THE INFORMATION SYSTEM



The arrows indicate information flows.

REFERENCES

1. Avery, R.W., "Enculuration in Industrial Research", IRE Transactions on Engineering Management, Vol. EM-7, No. 1, March 1960.

2. Ayers, R.U., Technological Forecasting and Long-Range Planning, McGraw-Hill, 1969.

3. Baker, N.R., "The Influence of Several Organizational Factors on the Idea Generation and Submission Behavior of Industrial Reserachers and Technicians", Ph.D. Dissertation, Northwestern University, January 1965.

4. Baker, N.R., J. Siegman, and J. Larson, "Characteristics of Industrial Research Proposals and Their Subsequent Disposition", presented at 1966 National Meeting of TIMS, Dallas, February 1966.

5. Baker, N.R., J. Siegman, and A. H. Rubenstein, "The Effects of Perceived Needs and Means on the Generation of Ideas for Industrial R and D Projects", IEEE Transactions on Engineering Management, Vol. EM-14, No. 4, December 1967.

6. Dean, B.V., and L.E. Hauser, "Advanced Material Systems Planning", IEEE Transactions on Engineering Management, Vol. EM-14, No. 1, March 1967.

7. Freeland, J.R., "A Model for Determining Skill Requirements in a Research Organization", M.S. Thesis, Georgia Institute of Technology, June 1970.

8. Kornhauser, W., Scientists in Industry: Conflict and Accommodation, University of California Press, Berkeley and Los Angeles, 19[illegible].

9. Marcson, S., The Scientist in American Industry, Harper and Brothers, New York, 1960.

10. Martino, J.P., "A Classification System for Military Functions, Technologies, and Sciences", IEEE Transactions on Engineering Management, Vol. EM-14, No.1, March 1967.

11. Rubenstein, A.H. "Organizational Factors Affecting Research and Development Decision-Making in Large Decentralized Companies", Management Science, Vol. 10, No. 4, July 1964.

12. Sigford, J.V., and R.H. Parvin, "Project PATTERN: A Methodology for Determining Relevance in Complex Decision-Making", IEEE Transactions on Enigneering Management, Vol. EM-12, No. 1, March 1965.